

“On the Density of Nitrous Oxide.” By LORD RAYLEIGH, O.M.
F.R.S. Received September 1, 1904.

In the ‘*Proceedings*,’ vol. 72, p. 204, 1897,* I have given particulars of weighings of nitrous oxide purified by two distinct methods. In the first procedure, solution in water was employed as a means of separating less soluble impurities, and the result was 3·6356 grammes. In the second method a process of fractional distillation was employed. Gas drawn from the liquid so prepared gave 3·6362. These numbers may be taken to represent the corrected weight of the gas which fills the globe at 0° C. and at the pressure of the gauge (at 15”), and they correspond to 2·6276 for oxygen.

Inasmuch as nitrous oxide is heavier than the impurities likely to be contained in it, the second number was the more probable. But as I thought that the first method should also have given a good result, I contented myself with the mean of the two methods, viz., 3·6359, from which I calculated that referred to air (free from H₂O and CO₂) as unity, the density of nitrous oxide was 1·52951.

The corresponding density found by M. Leduc is 1·5301, appreciably higher than mine; and M. Leduc argues that the gas weighed by me must still have contained one or two thousandths of nitrogen.† According to him the weight of the gas contained in my globe should be 3·6374, or 1·5 milligrammes above the mean of the two methods.

Wishing, if possible, to resolve the question thus raised, I have lately resumed these researches, purifying the nitrous oxide with the aid of liquid air kindly placed at my disposal by Sir J. Dewar, but I have not succeeded in raising the weight of my gas by more than a fraction of the discrepancy (1·5 milligramme). I have experimented with gas carefully prepared in the laboratory from nitrate of ammonia, but as most of the work related to material specially supplied in an iron bottle I will limit myself to it.

There are two ways in which the gas may be drawn from the supply. When the valve is upwards, the supply comes from the vaporous portion within the bottle, but when the valve is downwards, from the liquid portion. The latter is the more free from relatively volatile impurities, and accordingly gives the higher weight, and the difference between the two affords an indication of the amount of impurity present. After treatment with caustic alkali and sulphuric acid, the gas is conducted through a tap, which is closed when it is desired to make a vacuum over the frozen mass, and thence over phosphoric anhydride to the globe. For the details of apparatus, etc., reference must be made to former papers. The condensing chamber, which can be

* Or ‘*Scientific Papers*,’ vol. 4, p. 350.

† ‘*Recherches sur les Gaz*,’ Paris, 1898.

immersed in liquid air, is in the form of a vertical tube, $2\frac{1}{2}$ cm. in diameter and 22 cm. long, closed below and above connected laterally to the main channel.

The first experiment on July 13 was upon gas from the top of the bottle as supplied, and without treatment by liquid air, with the view of finding out the worst. The weight was 3·6015, about 35 milligrammes too light. The stock of material was then purified, much as in 1896. For this purpose the bottle was cooled in ice and salt* and allowed during about one hour to blow off half its contents, being subjected to violent shaking at frequent intervals. Subsequently three weighings were carried out with gas drawn from the bottom, but without treatment by liquid air. The results stand:—

July 18	3·6368
July 20	3·6360
July 25	3·6362

Mean	3·63633
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Next followed experiments in which gas, still drawn from the bottom of the bottle, was further purified by condensation with liquid air. The gas, arriving in a regular stream, was solidified in the condensing chamber. When it was judged that a sufficiency had been collected, the tap behind was turned and a *high* vacuum established over the solid mass with the aid of the Töpler pump. The pump would then be cut off and the gas allowed to evaporate and accumulate in the globe. A reapplication of liquid air caused the gas to desert the globe for the condensing chamber, until in a surprisingly short time a vacuum was re-established. Little or nothing could now be drawn off by the pump, and it was thought that a distinct difference could be perceived between the first and second operations, indicating that in the first condensation a little impurity remained gaseous. If desired, the condensation could be repeated a third time. On one occasion (August 7) the condensed gas was allowed to *liquefy*, for which purpose the pressure must rise to not far short of atmospheric, and to blow off part of its contents:—

August 1	3·6363
August 3	3·6367
August 7	3·6366

Mean	3·63653
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The treatment with liquid air raised the weight by only 0·2 milligramme, but the improvement is probably real. That the stock in

* The lower the temperature below the critical point, the more effective is this procedure likely to be.

the bottle still contained appreciable impurity is indicated by a weighing on August 13, in which without liquid air the gas was drawn from the *top* of the bottle. There appeared

August 13 3·6354,

about 1 milligramme short of the proper weight.

It will be seen that the result without liquid air is almost identical with that found by the same method in 1896, and that the further purification by means of liquid air raises the weight only to 3·6365. I find it difficult to believe that so purified the gas still contains appreciable quantities of nitrogen.

The corresponding weight of air being 2·3772,* we find that, referred to air as unity, the density of nitrous oxide is

$$\frac{3\cdot6365}{2\cdot3772} = 1\cdot5297.$$

Again, if oxygen be taken as 16, the density of nitrous oxide will be

$$\frac{3\cdot6365 \times 16}{2\cdot6276} = 22\cdot143.$$

The excess above 22 is doubtless principally due to the departure of nitrous oxide from Boyle's law between atmospheric pressure and a condition of great rarefaction. I hope shortly to be in a position to apply the correction which will allow us to infer what is the ratio of molecular weights according to Avogadro's rule.

* 'Roy. Soc. Proc.,' vol. 53, p. 134, 1893; 'Scientific Papers,' vol. 4, p. 47.